Will Decision Support in Medications Order Entry Save Money? A Return On Investment Analysis of the Case of the Hong Kong Hospital Authority

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The computerized medications order entry system currently used in the public hospitals of Hong Kong does not have decision support features. Plans are underway to add decision support to this system to alert physicians on drug-allergy conflicts, drug-lab result conflicts, drug-drug interactions and atypical dosages. A return on investment analysis is done on this enhancement, both as an examination of whether there is a positive return on the investment and as a contribution to the ongoing discussion of the use of return on investment models in health care information technology investments. It is estimated that the addition of decision support will reduce adverse drug events by 4.2 – 8.4%. Based on this estimate, a total net saving of $44,000 - $586,000 is expected over five years. The breakeven period is estimated to be between two to four years.

INTRODUCTION

The release of the Institute of Medicine's report "To err is human"[1] has focused attention on medication errors. In response, Computerized Physician Order Entry (CPOE) has been hailed as an effective tool to reduce medication errors. Indeed, a number of studies have demonstrated the potential of these systems to reduce medication errors.[2, 3]

Substantial investments in terms of hardware, software and manpower are involved in the implementation of CPOE systems. In one study, it was estimated that implementing CPOE at a 500-bed hospital would require a one-time capital plus operating cost of $7.9 million (all figures in this paper are in US$) and annual ongoing costs of $1.35 million.[4] In view of the need for budget constraints and heightened cost-consciousness, it has been proposed that a return on investment (ROI) analysis should be a standard requirement for major information systems applications projects before making contractual commitments.[5]

While few people will question the value of electronic order entry in improving safety and quality of patient care, its financial benefits per se may not be as self-evident. The fact that most of the returns from CPOE systems are indirect returns resulting from improved care, enhanced efficiency and care standardization adds to the difficulty of an ROI study. In this article we present our methods and results of an ROI analysis of a CPOE-related project in the public hospitals of Hong Kong.

BACKGROUND

Hong Kong has a population of 6.7 million. While 70% of primary health care is provided by the private sector, over 90% of secondary and tertiary health care is provided by public hospitals. In 1990, the Hospital Authority was established to manage all public hospitals in Hong Kong. Under the Hospital Authority, there are 14 major acute hospitals; nearly all of them (except one) have more than 1,200 beds. The Hospital Authority employs 4,200 physicians, 20,000 nurses and 4,000 allied health professionals. It manages about one million hospitalizations yearly and has an annual budget of $3.5 billion, mostly coming from the government.[6]

From its inception the Hospital Authority has adopted an aggressive approach promoting the use of information technology and information systems in its hospitals. Since 1996 all major hospitals are connected through a broadband wide area network. The presence of a territory-wide unique patient identifier (first implemented in 1991) greatly facilitates the sharing of clinical, laboratory and radiological data across different hospitals and health care providers. While a full-scale CPOE is not yet installed there is a basic computerized Medications Order Entry (MOE) system that allows direct entry from physicians. The MOE system is connected to the hospital pharmacy system. At present, MOE is mainly used in the outpatient setting but there are plans to extend it to the in-patient setting.

With regards to patient safety, the MOE system provides advantages over a pen-and-paper system by preventing errors related to illegible handwriting and misspelling of drug names. However, it has no effect on other types of medication errors because there is no built-in clinical intelligence. In order to enable the MOE system to alert physicians to drug-allergy conflicts, drug-lab result conflicts, drug-drug

interactions and atypical dosages, some decision support abilities need to be installed. To achieve this, a Medications Order Decision Support (MODS) module that will issue advice based on both patient- and order-specific data has been proposed as an addition to MOE. The costs and returns of this enhancement of MOE are the subject of this study.

METHODS

Definitions of terms

Medication errors are defined as errors occurring at any stage during the process of ordering or delivering a medication. They include the entire range of error severity from trivial to life threatening. Adverse drug events (ADEs) are defined as injuries resulting from medical interventions related to a drug.[7] Preventable ADEs are ADEs caused by medication errors.[1] ADEs that do not result from medication errors are non-preventable ADEs. The relationship between these entities is shown diagrammatically in Figure 1.

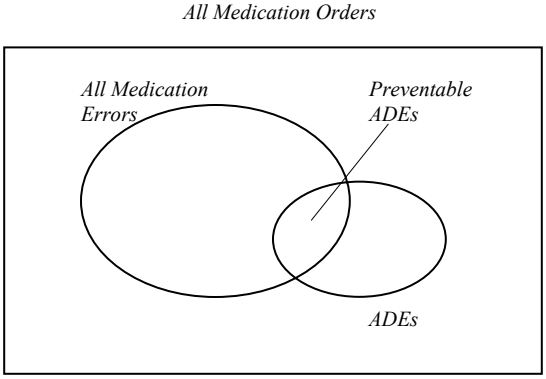

Figure 1. Relationship between medication orders, medication errors, ADEs and preventable ADEs

Calculation of costs and returns

Costs and returns for the MOE enhancement are calculated over a period of five years. For the calculation of costs, three categories of expenditures are considered: software license, hardware costs and development/maintenance manpower. Because the MODS module does not lead to a significant change in the user interface of the MOE system, we can assume that user training and ongoing support costs will be unlikely to increase.

In the estimation of returns, it is assumed that the most significant return will be the avoidance of extra health care costs resulting from ADEs. The magnitude of this saving is estimated from data available in the medical literature on the incidence, cost and preventability of ADEs. Other potential savings such as manpower costs related to the handling of trivial errors, reduction of liability claims and costs of injuries to patients are not enumerated.

RESULTS

Cost of implementing MODS

Software – the software package involves an upfront payment of $148,000 for licensing as well as recurring fees of $37,200 for the first year and $73,200 per year from the second to the fifth year for software maintenance.

Hardware – it is estimated that the MOE system will be extended to the in-patient setting in a stepwise manner, starting from 20% coverage in the first year and increasing to full coverage by the fifth year. Initially no hardware investment is required for the MODS module because the additional computing workload of MODS can be absorbed into the current hardware capacity. However, it is estimated that an additional hardware investment of $10,000 per year from the third year onwards will be required.

Manpower – for the initial development, six man-months ($18,000) will be required. As a lot of the preliminary work has already been done when MOE was installed, the marginal development cost for MODS is relatively small. Subsequently, two man-months ($6,000) will be required each year for minor maintenance work.

Savings attributable to MODS

In order to estimate savings attributable to the addition of MODS, we need to know the overall incidence of ADEs, their total costs and the proportion of ADEs that is expected to be prevented by MODS.

Total incidence of ADEs – The overall incidence of ADEs is estimated from two large-scale studies, the Harvard Medical Practice Study [8] and the Colorado and Utah Study [9]. The Harvard study found that 3.7% of hospitalizations suffered from adverse events among which 19% were ADEs. The corresponding figures in the Colorado and Utah study are 2.9% and 19% respectively. For this study, average figures of 3.3% and 19% are used.

Costs of ADEs – Reference is made to two studies in the estimation of the cost of ADEs. According to Bates et al. each ADE caused an average of 2.2 days of extra hospital stay.[10] Classen et al. found a slightly lower figure of 1.7 extra days for each ADE.[11] For this study an average figure of 2 days per ADE is used. For the Hong Kong Hospital Authority the cost

of one day of hospital care is $410. With one million hospitalizations yearly, the total cost of ADEs per year is therefore:

1,000,000x3.3%x19%x2x$410 = $5,141,400

Percentage of ADEs that will be prevented by MODS – Not all ADEs are potentially preventable. In four studies carried out in secondary and tertiary care institutions, the percentage of preventable ADEs were found to be 50%, 28%, 56% and 28% of all ADEs. [11-14] For this study, an average figure of 40% is used. Medication errors can occur at different stages of the medication process, which includes prescribing, dispensing, administering and monitoring. MODS will only have an impact on prescribing errors. According to a study by Bates et al, [14] prescribing errors accounted for 56% of preventable ADEs. Prescribing errors occur due to a variety of reasons including illegible handwriting, misspelt drug names or incorrect abbreviations - all already amenable to interception by the plain MOE system. The addition of MODS will help further in preventing medication errors caused by drug-allergy conflicts, drug-lab result conflicts, drug-drug interactions and erroneous dosage calculations by incorporating a patient's clinical data into the ordering process. In a study by Lesar et al, [15] these errors constitute about 75% of all medication errors with the potential to cause ADEs.

It would be overly optimistic to assume that all ADEs theoretically preventable by MODS will be prevented. For instance, if a patient's allergy information is not captured properly in the electronic medical record, MODS will not be able to prevent prescription of the offending drug. For this study, we have arbitrarily assumed that MODS will successfully prevent 25 – 50% of all ADEs that it can ever prevent. We call this the chance factor – the chance that an error that should be prevented will actually be prevented.

The above series of assumptions is summarized in Table 1. The overall reduction in ADEs attributable to MODS, calculated by multiplying all the reduction factors together, ranges from 4.2% (low estimate) to 8.4% (high estimate).

Refinement	Reduction Factor
All ADEs	100%
Preventable ADEs	40%
Preventable ADEs due to prescribing errors	56%
Prescribing errors preventable only with MODS	75%
Chance factor	25% - 50%
Overall % of ADEs prevented by MODS	**4.2% - 8.4%**

Table 1. Estimation of the proportion of ADEs that will be prevented by MODS

Return On Investment calculation

On the cost side, the total one-off cost is $166,000, including software license and labor. The subsequent yearly recurrent costs are calculated accordingly (Table 2). On the return side, if all in-patients are covered by MOE, the yearly cost saving will be: Cost of ADEs x % of ADEs prevented by MODS.

This amounts to $216,000 ($432,000) according to the low (high) estimate. The expected cost saving in each year is calculated according to the percentage of in-patients that will be covered by MOE in that year. To facilitate comparison between costs and savings that occur at different points in time, all figures are discounted to present value by an arbitrary discount rate of 5% per annum (Table 2).

The net present value (NPV) of the project is calculated by subtracting the total discounted expenditure from the total discounted saving. This amounts to approximately $44,000 and $586,000 for the low and high estimate respectively. As both values are positive, this means that there will be a net saving over the five-year period by either estimate.

Another way to look at return on investment is to estimate the breakeven period – the time taken for return to balance off investment. By plotting the

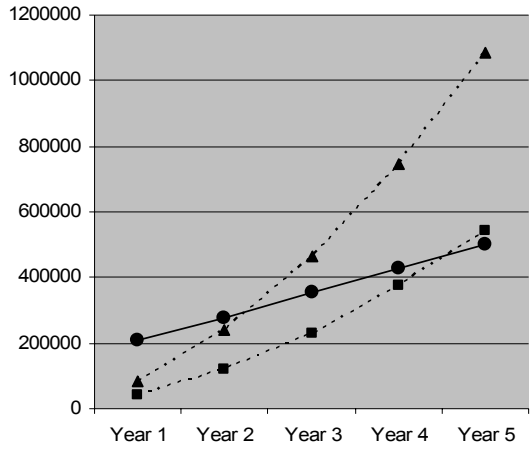

Figure 2. Comparison of cumulative expenditure and return over time (to estimate breakeven period). −●− cumulative expenditure; --■--cumulative return (low estimate); --▲-- cumulative return (high estimate). All figures discounted to present value.

	Start	Year 1	Year 2	Year 3	Year 4	Year 5	Total	NPV
Investment: Initial investment	166,000							
On-going software		37,200	73,200	73,200	73,200	73,200		
On-going labor		6,000	6,000	6,000	6,000	6,000		
Future capital investment				10,000	10,000	10,000		
Total yearly expenditure	166,000	43,200	79,200	89,200	89,200	89,200		
Present value of expenditure	166,000	41,142	71,836	77,054	73,385	69,891	499,308	
Return: % In-patient utilization		20%	40%	60%	80%	100%		
Yearly cost savings (low estimate)		43,200	86,400	129,600	172,800	216,000		
Yearly cost savings (high estimate)		86,400	172,800	259,200	345,600	432,000		
Present value of savings (low estimate)		41,142	78,367	111,953	142,163	169,241	524,868	43,560
Present value of savings (high estimate)		82,285	156,734	223,906	284,326	338,483	1,085,736	586,428

Table 2. Yearly expenditures and cost savings and their present values calculated at a discount rate of 5% per annum. (NPV- net present value)

cumulative cost and cumulative expenditure over time it can be seen that the breakeven period is between 2 to 3 years for the high estimate and between 4 to 5 years for the low estimate. (Figure 2)

DISCUSSION

In this study we have attempted to quantify the economic benefits of the addition of clinical decision support to the medications order entry system. In the estimation of cost savings, we have only considered reduction in hospitalization costs attributable to the avoidance of ADEs. There are other potential cost savings that we have not included in our calculations because they are more difficult to quantify.

Firstly, all medication errors have cost implications. This is true even if they are not associated with ADEs because they are trivial in nature or they have been intercepted. These non-consequential medication errors result in wasted personnel time and inefficiency. Imagine the case in which the ward nurse notices that ampicillin is ordered for a patient with a history of allergy to penicillin. The drug is not administered and no ADE results from this medication error. However, the drug has to be transported back to pharmacy and the responsible physician has to be contacted to change the order to another drug. According to one study about 20 minutes of extra work is wasted in each medication error, mainly involving nurses and pharmacists. For a hospital with 1,000 beds this wastage is equivalent to a cost of almost $300,000 per year. [16]

Another potential source of cost savings that we have not included in our calculations is the reduction in liability claims related to malpractice litigation. Very little data is available in the medical literature to allow any meaningful estimation of savings in this respect. It is likely, however, that such savings will not be trivial.

Apart from direct costs to the health care providers, ADEs also have indirect costs borne by society as a whole. These indirect costs include lost productivity, disability costs and personal costs of care. Thomas et al. estimated that the total national costs (lost income, lost household production, disability and health care costs) related to medical adverse events in the U.S. is $37.6 billion, of which only about half represents direct health care costs.[17]

In the estimation of the percentage of ADEs that will be prevented with the addition of MODS, we have adopted a 'trim-down' approach. In a stepwise fashion we exclude ADEs that are: not potentially preventable, not due to prescribing errors and already preventable without MODS. Finally, we add a chance factor to reflect unexpected failures of MODS. Some studies have directly measured the impact of CPOE on the incidence of ADEs. Bates et al. found that a CPOE system that includes a dose selection menu, simple drug-allergy and drug-drug checking caused a 17% reduction in preventable ADEs.[2] If we assume that preventable ADEs represent about 40% of all ADEs (the ballpark figure we use in this study), this will translate into a 6.8% reduction of all ADEs,

which is in agreement with our estimation of 4.2 – 8.4%.

Despite the purely economic approach taken in this study, it has to be emphasized that investment decisions in healthcare IT should not be made on economic considerations alone. As stated by Lucas, not all IT investments should be expected to show a measurable return. Investments can have value to an organization even without demonstrable financial return.[18] Sometimes healthcare IT projects that do not produce a positive NPV can be supported on qualitative grounds alone.[5] Investment in CPOE systems could probably be justified based solely on their positive effect on the quality of patient care. However, despite the widely-quoted benefits, fewer than 5% of hospitals in the US have CPOE.[4] One of the obstacles of implementing CPOE is cost, particularly in view of dwindling hospital IT budgets. It has been found that current IT spending in hospitals as a percentage of total operating expense has dipped to its lowest since 1998.[19] It is hoped that by demonstrating a favorable ROI in CPOE-related investments the financial obstacle of CPOE implementation can be more readily overcome.

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